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# PRODUCT SUITABILITY OF WOOD . . .

## determined by density gradients across growth rings

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*Abstract:* The suitability of wood for various uses can be determined by synthesizing single growth-ring density curves from accumulated means of wood density classes. Wood density gradients across growth rings were measured in large increment cores from 46-year-old ponderosa pines *(Pinus ponderosa* Laws.*)* by using X-rays. Of the 48 trees analyzed, 36 had been thinned 10 years earlier, then fertilized; six had been thinned only; and six were unthinned. Wood density distribution curves for growth rings in all trees were combined to produce a single representative curve for each group of trees. Relative tree values were determined by applying density quality factors to tree volumes.

*Oxford:* 174.7 *Pinus ponderosa:* 812.31 [+815.2 + 562.22 + 237.44].
*Retrieval Terms: Pinus ponderosa;* wood density; fertilizer response; thinning effects; growth rate; utilization potential.

Wood density in ponderosa pine *(Pinus ponderosa* Laws.*)* averages about 0.42 when ovendry.[1] This density is relatively low when compared to that of Douglas-fir (0.51) and southern pine (0.52–0.66). Because old-growth ponderosa pine wood has a fairly uniform structure, it has traditionally been preferred for millwork (sash, doors, and screens) and for planing mill products, such as interior finish, trim, siding, and paneling. Lumber from young-growth trees often contains wide growth rings with dense latewood and is used for building construction where stresses are not too great. The differences noted visually in the wood of young- and old-growth ponderosa pine can now be determined by slopes of density gradients across growth rings. Until recently, however, no satisfactory way of determining this gradient, or density distribution, has been available.

Interest in wood density distribution within individual growth rings has coincided with development of techniques for evaluating this characteristic.[2, 3, 4] The patterns of density distribution basically influence mean density as well as percent latewood.[5] If a pattern can be shown as characteristic of a tree or stand, it can be interpreted in terms of the wood quality of that tree or stand. Density distribution and mean density provide a measure of wood uniformity and suggest its degree of suitability for end uses.

This note describes the use of the accumulated means of wood density classes to synthesize single growth-ring density curves. Each curve is representative of all trees in a single experimental treatment. The distribution of wood density across growth rings is also used to evaluate the trees in terms of potential products.

### METHODS

Three groups of ponderosa pine trees in the west-side Sierra Nevada foothills were sampled by extracting 12-mm-diameter increment cores from bark to pith at breast height. The 46-year-old trees had an

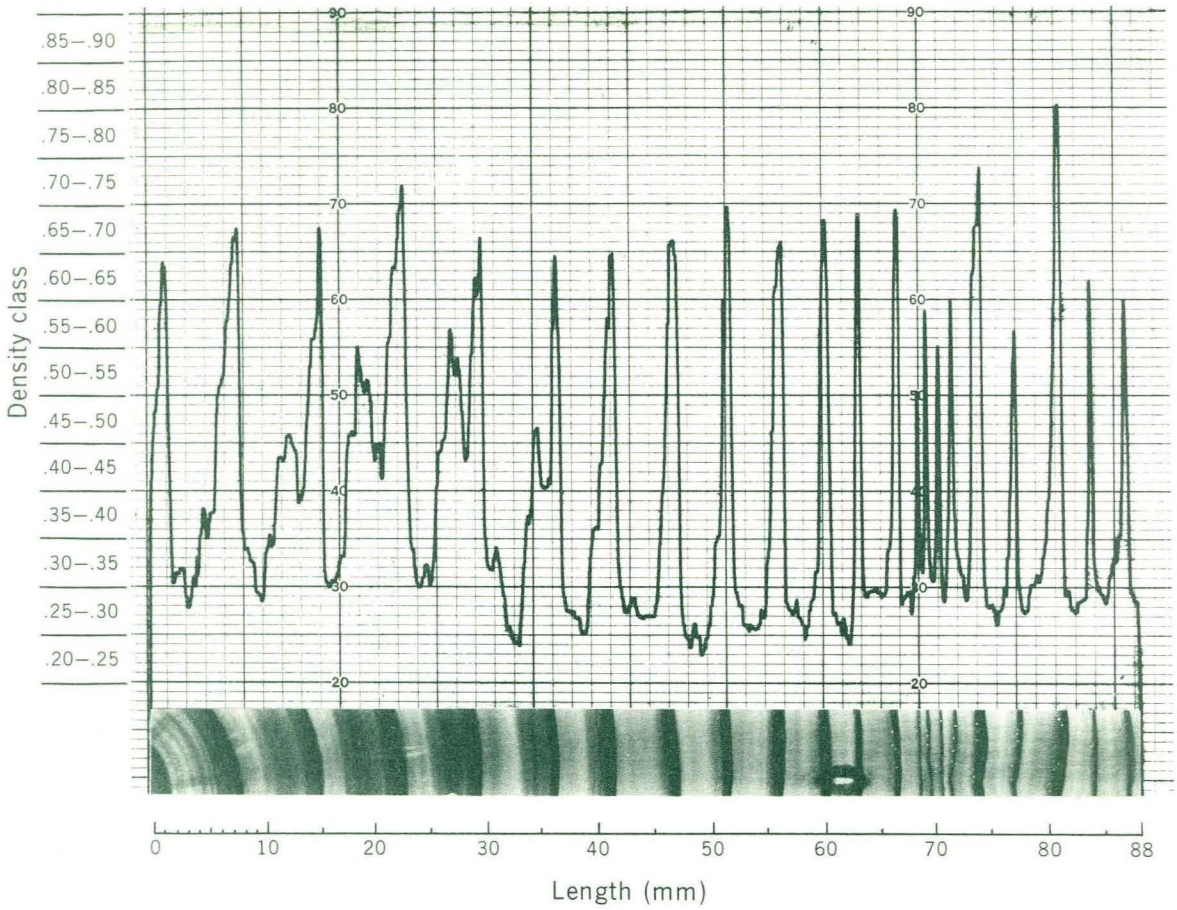


**Figure 1**—Microdensitometer chart tracing and X-ray (positive print) of ponderosa pine increment core. Mean wood density as shown is 0.347.

average diameter of 17 inches at breast height and an average height of 76 feet. Two of the groups had been thinned in 1961 to create a seed production area from the natural stand. Crop trees were spaced 30 to 40 feet apart. In 1962, one group of thinned trees was fertilized to learn the effects on flowering and cone production. Since no differential effects were noted for various fertilizer combinations, the treated trees were pooled to represent a nitrogen fertilizer treatment. Thus, 36 trees that had been thinned and fertilized (TF), six trees that had been thinned only (T), and an additional six trees that had been neither thinned nor fertilized (UT) were cored for this study.

The increment cores were conditioned to 12 percent moisture content and X-rayed by using the moving-silt procedure to avoid parallax distortions.[2] The X-ray negatives were analyzed with a microdensitometer that produced chart tracings representing wood density variations *(fig. 1)*. Simultaneously an integrator measured density distribution by dividing the entire range of density into 14 classes (0.20–0.90) and recorded the total amounts of wood in each 0.05 class across all of the growth rings in each core.

A density distribution (DD) index was derived for each wood sample. This number indicated the amount and relative distribution of wood in all of the density classes in the sample. It was obtained by summing the weighted percentages of wood in each density class, as shown in *table 1*.

The weighting factors are based on the number of classes above and below the class that contains the mean density. Hence, the greater the variation the larger will be the DD index. A variation in density of only ± 0.15, or three 0.05 classes, would give a DD index of 100. This is the lowest number possible, since the percentages of wood in the classes always total 100, and the three weighting factors are 1 for the class containing the mean, 1 for the class above, and 1 for the class below the mean.

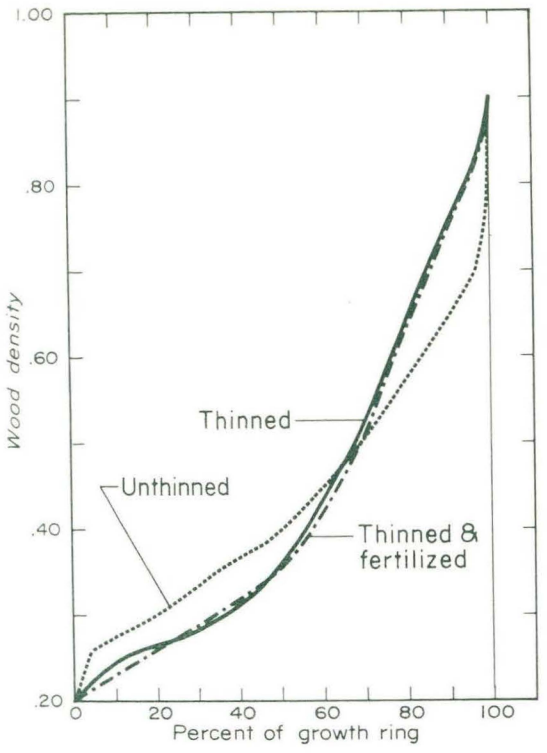


**Figure 4—Wood density distribution in a 48-tree sample of 46-year-old ponderosa pines, adjusted to one standard ring width for all three treatments (trees thinned and fertilized, thinned only, and unthinned).**

density distribution curves are compared with a base, or optimum (curve A, *fig. 3*), the quality of the wood can be estimated closely. Curves for wood with a high degree of uniformity would tend toward the horizontal, with very steep tails. As wood density distribution expands to cover additional density classes, the curves will become more vertical and sigmoid, with increased percentages of wood in lower and higher density classes.

## APPLICATION

When mean wood density and density distribution are known, they could be used as a guide to the suitability of wood for its various uses *(fig. 5)*. As such they would be key items in forest, stand, and even stockpile inventory data. For example, a wood with a high degree of uniformity and with medium to high mean density could be converted into higher value products, with somewhat lower production costs, than wood with low density and highly contrasting earlywood and latewood. The latter would be suitable only for medium or low-value products.

Relative values can be assigned to trees when their density distributions are plotted against mean densities *(fig. 6)*. Assuming that the highest quality wood has 75 percent greater value than the lowest on the chart, quality zones that include intermediate values were superimposed. The quality factors were then applied as multipliers to the relative volumes of wood in the individual trees of this study. For wood produced after treatment, thinning increased the value over unthinned trees by an average of 121 percent. Application of fertilizer resulted in a further value increase of 12.5 percent over the trees that were thinned but not fertilized.

Wood density distribution, or uniformity, is an important characteristic in the determination of wood quality. When considered along with mean density it provides an index to the type of conversion processes and products most suitable for the wood. Applied to tree volumes it yields value estimates that can be used to assess inherent growth and treatments.

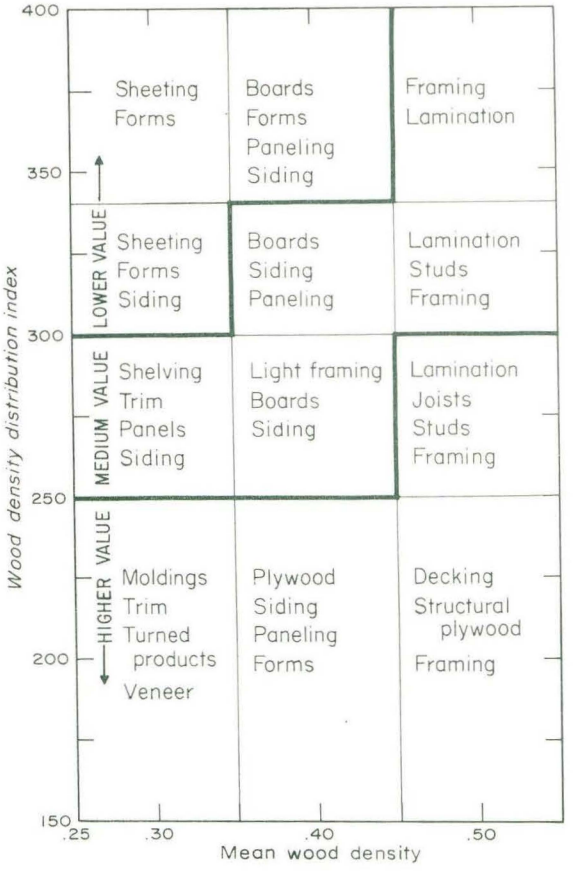


**Figure 5—This hypothetical guide to utilization of ponderosa pine is based on mean wood density and density distribution (DD). The smaller the number on the vertical scale, the more uniform the wood across growth rings. Letter symbols refer to trees in study.**

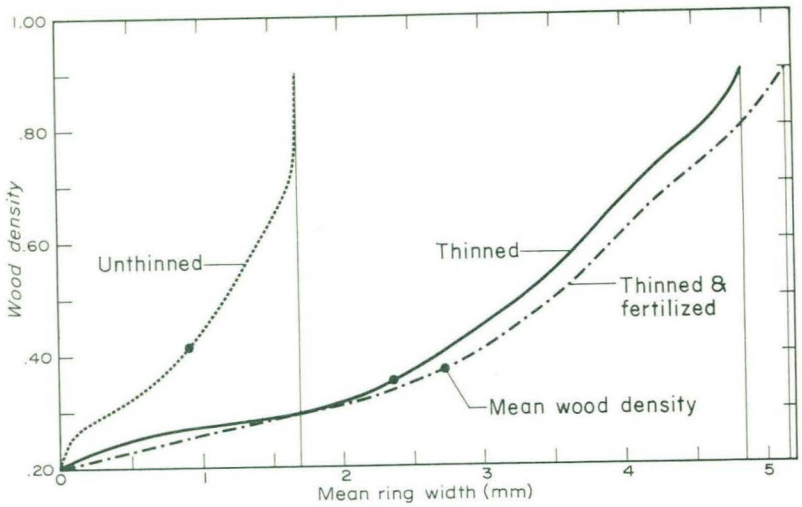


**Figure 2**—Wood density distribution in a 48-tree sample of 46-year-old ponderosa pines. Each curve is a composite of all rings in all trees in a single treatment, expressed in terms of mean ring width.

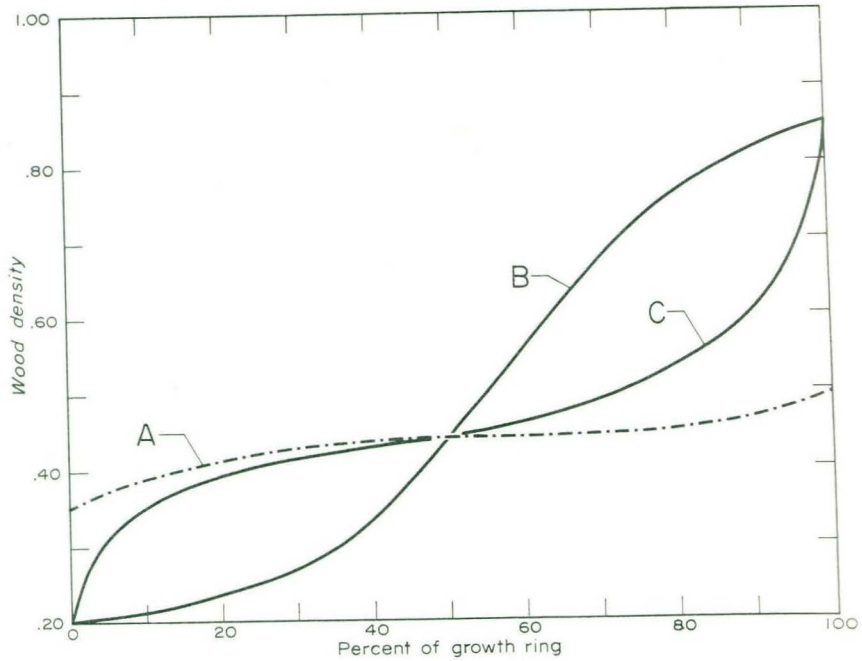


**Figure 3**—Wood density distribution for three trees adjusted to one standard ring width. Density Distribution index for tree A = 100, tree B = 181, and tree C = 417. Mean density for all trees = 0.44.

wood, making it more difficult to shape, peel for veneer, or to nail without splitting.

When the composite data in this study were adjusted to one standard ring width for all three treatments, similar results were obtained *(fig. 4)*. The findings can be applied to the stands of trees if these assumptions are made: (a) The increment core is indicative of the wood in the tree (several studies have related single increment cores to merchantable stems with very high levels of significance); and (b) the trees sampled are representative of the full stand. It becomes simply a matter of determining the right sample size and pattern.

In the UT stand, 35 percent of the wood had density below 0.35; in the T and UT stands, nearly 50 percent of the wood was below 0.35 density *(fig. 4)*.

In the UT stand, 10 percent of the wood was above 0.65; in the T and TF stands, 20 percent of the wood was above 0.65 density.

In other words, the UT trees (with less than half the ring width or volume per tree) had 55 percent of their wood between 0.35 and 0.65 density. Both T and TF trees had only 30 percent of their wood between 0.35 and 0.65 density.

Single composite growth rings can reveal the character of wood in a tree or stand at a glance. When

## RESULTS

Response of the trees to the 1961 thinning was highly significant for average growth and wood density distribution, in comparison to that of the unthinned trees *(table 2)*. Wood densities were not significantly different, although the normal density increase with age in unreleased trees was evident.

For further comparisons, the density distribution data were combined to produce three single, synthetic growth ring curves *(fig. 2)*. These curves are composites of all rings in all trees in each of the three treatments (UT, T, and TF). The density values were correlated with the actual amounts of wood in each density class, so that they are expressed in terms of their share of the width of the growth ring. Thus, for the 1.69 mm of mean ring width in the UT stand, 0.4 mm (or from 0.62 to 1.02 mm) of ring width had a density of 0.35 to 0.45. The T stand, with 4.85 mm mean ring width, had 0.9 mm in the 0.35–0.45 density range; and the TF trees had 0.8 mm of ring width in that range, out of 5.15 mm total.

The relative distribution of wood density increments in different trees or groups of trees can be determined both visually and numerically by adjusting all data to one standard ring width. When plotted graphically with the X-axis representing percent of growth ring and the Y-axis wood density, variations in density distribution become more obvious. In *figure 3*, curves A, B, and C represent trees all having mean wood density of 0.44.

Curve A represents an ideally uniform wood with density variation confined to only three density classes: 0.35–0.40, 0.40–0.45, and 0.45–0.50. The DD index is 100, since the percent of wood in one class above and below the mean, plus that in the class containing the mean, totals 100. Very seldom is this degree of uniformity found in wood; usually the density distribution ranges from that of curve B (DD = 181) to the more extreme variation represented by curve C (DD = 417). The wood in curve C would have soft, distinct earlywood and hard, pronounced late-

Table 1–*Derivation of DD Index from percent of wood in each density class. Scale of weighting factors based on class containing mean density*

| Density class | Wood in class | Weighting factor (multiplier) | Density Distribution Increments |
|---|---|---|---|
| | *Pct.* | | |
| 0.85-0.90 | 0.6 | 10 | 6.0 |
| .80- .85 | 1.6 | 9 | 14.4 |
| .75- .80 | 3.2 | 8 | 25.6 |
| .70- .75 | 3.8 | 7 | 26.6 |
| .65- .70 | 4.0 | 6 | 24.0 |
| .60- .65 | 4.2 | 5 | 21.0 |
| .55- .60 | 4.6 | 4 | 18.4 |
| .50- .55 | 5.1 | 3 | 15.3 |
| .45- .50 | 5.5 | 2 | 11.0 |
| .40- .45 | 7.2 | 1 | 7.2 |
| .35- .40 | 9.0 | 1 | 9.0 |
| .30- .35 | 14.0 | 1 | 14.0 |
| .25- .30 | 24.1 | 2 | 48.2 |
| .20- .25 | 2.4 | 3 | 7.2 |
| Total | 100.0 | | 248 |

Mean density = .37
DD Index = 248

Table 2–*Nine-year average changes in growth, wood density, and wood density distribution in ponderosa pine trees before and after thinning and fertilization*

| Item | Width of 9-year increment | | | Wood density | | | Wood density distribution index[1] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Before 1961 | After 1961 | Change | Before 1961 | After 1961 | Change | Before 1961 | After 1961 | Change |
| | | | *Pct.* | | | *Pct.* | | | *Pct.* |
| Unthinned (six trees) | 23.3 | 15.2 * | -35 | 0.350 | 0.414 | +18 | 248 | 227 | - 8 |
| Thinned (six trees) | 33.2 | 43.7 ** | +32 | .366 | .350 | - 4 | 284 | 318 ** | +12 |
| Thinned and fertilized (36 trees) | 34.7 | 46.3 ** | +33 | .342 | .352 | + 3 | 282 | 308 ** | + 9 |

[1] Increasing number = greater density variation
* Statistically significant at 5 percent level of probability according to Student's t test.
** Statistically significant at 1 percent level of probability according to Student's t test.

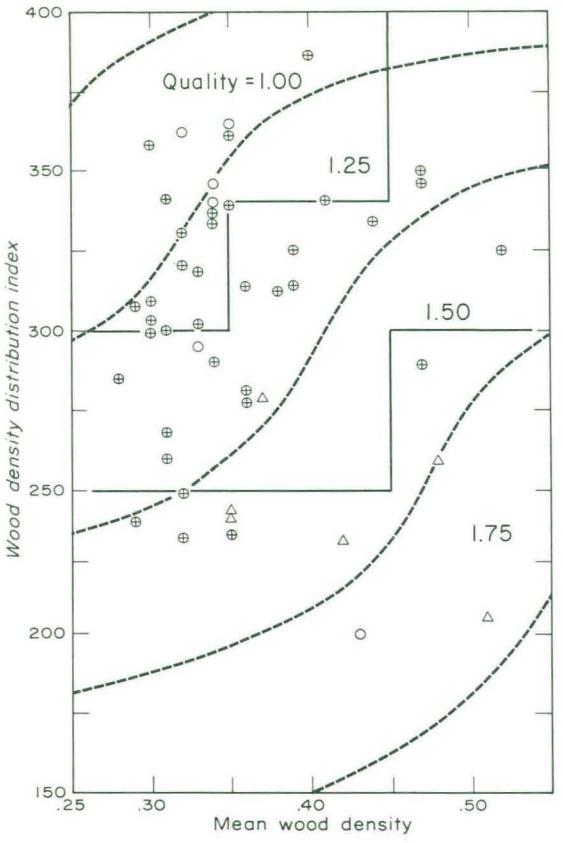


**Figure 6**—Relative values of the unthinned (△), thinned (○), and thinned and fertilized (⊕) trees in terms of wood products. Quality factors of 1.00 – 1.75 assigned on basis of DD and mean wood density in designated zones.

## NOTES

[1] Panshin, A. J., and Carl de Zeeuw. *Textbook of wood technology.* Vol. I, 643 p. New York: McGraw-Hill Book Co. 1964.

[2] Echols, R. M. *Moving-slit radiography of wood samples for incremental measurements.* Univ. British Columbia Faculty of Forestry Bull. 7, p. 34-36. 1970.

[3] Harris, J. Maddern, and H. Polge. *A comparison of X-ray and beta ray techniques for measuring wood density.* J. Inst. Wood Sci. 4: 34-42. 1967.

[4] Kennedy, R. W. *Intra-increment variation and heritability of specific gravity, parallel-to-grain tensile strength, stiffness and tracheid length in clonal Norway spruce.* Tappi 49(7): 292-296. 1966.

[5] Echols, R. M. *Patterns of wood density distribution and growth rate in ponderosa pine.* Proc. Symp on Effect of Growth Acceleration on the Properties of Wood, Madison, Wis. 1971: H1-H18, illus. Madison: U.S. Forest Prod. Lab. 1972.

### The Author

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